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TEST OF DEPARTMENT OF ENERGY STRATEGIC PETROLEUM RESERVE BAYOU CHOCTAW CAVERN 17

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ABSTRACT

This report documents the cavern integrity test of Bayou Choctaw cavern 17 conducted between October 16 and December 30, 1985. This test included a nitrogen leak test of the single cavern entry well, 17, at near maximum operating pressure. Test results indicate a nitrogen loss rate of 840 bbl/yr. This leak rate can reasonably be assumed to correspond to an oil loss rate of 84 bbl/yr, compared to the Department of Energy loss limit goal of 100 bbl/yr.

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INTRODUCTION

Bayou Choctaw cavern 17 was an ethane storage cavern formerly owned by Union Texas Petroleum (UTP). Ethane was transferred from the cavern into Bayou Choctaw cavern 102 in the summer of 1985. Bayou Choctaw cavern 102, owned by the U.S. Department of Energy (DOE), was exchanged with UTP for Bayou Choctaw cavern 17 effective December 3, 1985. The DOE plans to use Bayou Choctaw cavern 17 for crude oil storage in the Strategic Petroleum Reserve (SPR) program.

As part of the exchange agreement, UTP began a cavern integrity test program on August 8, 1985. Responsibility for technical monitoring of the test program was delegated to Sandia National Laboratories (SNL) by the DOE/SPR Project Uanagement Office. PB/KBB, which is a contractor to the management operation and maintenance contractor for SPR, Boeing Petroleum Service, Inc. (BPSI), worked with UTP and SNL in the implementation of the test program. At the time the cavern exchange became effective on December 3, 1985, the cavern integrity test program had not been completed. The program was continued to completion on December 30, 1985, by SNL and PB/KBB.

The planned test program included a brine-filled cavern pressure test followed by a nitrogen well leak test as described in Ref. 1. The initial brine-filled cavern pressure test was begun August 8, 1985. The test resulted in significant transients due to interactions with cavern 15, which is separated from cavern 17 by a salt web which may be as thin as 100 feet. Results of this test have not been satisfactorily interpreted. Following this initial brine pressure test, the cavern was depressurized, hanging strings were removed from the well, and a sonar survey of the cavern was performed.

A nitrogen well leak test of the single entry well, 17, was started October 16, 1985. This nitrogen well test is considered an adequate cavern integrity test and is documented herein.

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CAVERN DESCRIPTION

Cross sections of the cavern in the north-south and the east-west directions are shown in Figures 1 and 2, respectively. These figures are from a sonar survey of September 30, 1985, (Ref. 2) which indicates a cavern volume of 10.76 x 10^6 bbl.

The entry well into the cavern, well 17, has a 20-inch casing to a depth of 594 feet, a 13-3/8-inch last cemented casing to 2597 feet, and a 10-3/4-inch liner cemented to 2536 feet. As indicated by Figures 1 and 2, the cavern opens to a diameter of about 50 feet very near the casing seat.

INSTRUMENTATION

Pressure

Wellhead pressure on cavern 17 was measured using a Sperry Sun "Mr. Six" pressure recording system. A separate Sperry Sun "Mr. Six" system was used for measuring wellhead oil and brine pressures on the adjacent cavern 15. It was considered important to monitor pressures in cavern 15 because of the relatively thin web between the two caverns, the interaction between the two caverns due to pressure changes, and the probability that any leak which might occur in cavern 17 below the well would probably be into cavern 15.

Each "Mr. Six" system sequentially digitized and recorded on paper tape the wellhead pressure and pressure probe temperature for each individual probe at pre-selected time intervals. Subsequently, the data from the "Mr. Six" paper tapes were stored on magnetic tape for processing with a Hewlett Packard 85 computer.

Flow

Brine volume injected into cavern 17 was measured by UTP using a 4-inch Halliburton turbine flow meter. Oil volume injected into cavern 15 was measured by BPS using the SPR site custody transfer meter, a lo-inch Daniels turbine meter.

Nitrogen Xeasurement

In preparation for the nitrogen well leak test, nitrogen was injected into the well and measured by NOWSCO using a mass flow measurement system developed by Micro Motion. During nitrogen injection into the lower cased part of the well and the open hole below, weight of nitrogen injected was recorded simultaneously with pressure and nitrogen-brine interface depth.

Interface Depth

Nitrogen-brine interface depth was measured by use of an AGAR interface detector. The detector transmitted a radio frequency signal from an antenna into the fluids. The attenuation level of the transmitted signal was indicative of the location of the interface on the antenna. For depths down to 2596 feet, recorded interface depths were those indicated by the digital depth meter on the interface tool wire line system. Increments of interface movement below 2596 feet, where the borehole rapidly enlarged, were determined by measuring distance between a fixed point on the wellhead and an arbitrary marker on the interface tool wire line.

TEST DESCRIPTION

Cavern Pressurization

Cavern 17 was pressurized to a surface pressure of 652 psig (a pressure gradient of 0.77 psi/ft to the casing seat, compared with a maximum working pressure gradient of 0.79 psi/ft) by injection of brine through a turbine flow meter during a two-day period starting October 16 (see Figure 3a at times of 9 to 58 hours). Concurrently, cavern 15 was pressurized to 933 psig by injection of oil through a turbine flow meter into well 15, which is a slick hole (see Figures 3c and 3d at times of 9 to 46 hours). The two caverns were pressurized concurrently in order to minimize the change in pressure difference across the thin salt web between the two caverns. The pressure in cavern 17 at the 2600-foot depth was higher than that in cavern 15 at the same depth by about 100 psi at both the beginning and end of the pressurizations. During the pressurizations, the pressure in cavern 17 was higher by values ranging from about 20 to 130 psi.

Following pressurization, cavern 17 was shut in for about 5 days (to 177 hours on Figure 3a).

Nitrogen Injection

On October 23-25, nitrogen was injected into well 17 to a depth about 2 feet below the casing seat, at which time the wellhead pressure was 1856 psig (see Figure 3a at 177 to 203 hours).

Nitrogen weight and wellhead pressure were recorded at nitrogen-brine interface depths from 1500 to 2500 feet at intervals of 100 feet, from 2500 to 2596 feet at intervals as small as 6 feet, and below 2596.5 feet at intervals of inches and fractions thereof. These measurements were for the purpose of calculating borehole volume below the casing seat. The procedure used for the calculation is described in Appendix A of Ref. 3.

TEST RESULTS

Cavern Elasticity

Cavern 17 pressure-volume data during pressurization are presented in Figure 4a and indicate an average elasticity value of 31.3 bbl/psi for the brine-filled cavern. Cavern 15 data are presented in Figure 4b. For cavern 15, brine pressures indicate an average elasticity value of 89.4 bbl/psi, whereas oil pressures indicate an elasticity value of 82.9 bbl/psi for this oil-filled cavern. The difference has not been explained.

For cavern 17, with a reported volume of 10.76 x 10^6 bbl, and filled with brine having an elasticity of 2.25 x 10^{-6} bbl/bbl/psi, the cavern fluid elasticity would be 24.2 bbl/psi. This indicates that of the 31.3 bbl/psi value determined from pressurization results, 7.1 bbl/psi is due to salt elasticity.

Cavern 15 has a reported volume of 16.46 x 10^6 bbl and contains an oil volume of 16.13 x 10^6 bbl. With the remaining volume filled with brine, and with an assumed oil elasticity of 4.97 x 10^{-6} bbl/bbl/psi, the cavern fluid elasticity is 80.9 bbl/psi. The cavern elasticity of 89.4 bbl/psi, indicated by the brine pressure results of Figure 4, would correspond to a salt elasticity of 8.5 bbl/psi. The cavern elasticity indicated by the oil pressure data of Figure 4 would correspond to a salt elasticity of only 2.0 bbl/psi.

Cavern Shut-In at Maximum Operating Pressure

The cavern 17 pressures following shut-in at maximum operating pressure are shown on the expanded scale plot of Figure 3b. The gap in the data occurred when the "Mr. Six" had to be removed for repair. Immediately following re-installation, pressure readings were unexplainably high for about 6 hours. With the exception of these readings, the results of Figure 3b are as normally expected for a "good" cavern with pressures decaying following pressurization and shut-in, but with the rate of decay decreasing with time.

Borehole Caliper from Measurements During Nitrogen Injection

Calculated nitrogen column cross-sectional areas for well 17, using the procedures described in Appendix A of Ref. 3, are shown in Figure 5. Included in the figure are measured values of interface depth, wellhead nitrogen pressure, and incremental values of nitrogen weight injected between interface depths.

In defining the interface depths of Figure 5, depths down to 2596 feet were obtained directly from the digital depth meter on the interface tool wire line system. Below 2596 feet, it was apparent that nitrogen was spilling out into an enlarged cross section. The first measurement following that at 2596 feet was called 2596.5 feet. Subsequent incremental depth readings were determined from measurements between a reference point on the wellhead and an arbitrary reference point on the wire line. These measurements were made using a steel scale and readings were to the nearest one-sixteenth of an inch (0.005 foot). While the interface depths of Figure 5 are certainly not as accurate as implied by the readings, the increments below 2596.5 feet are believed accurate to well under one inch. The increments are of primary importance in calculation of nitrogen column cross-sectional area.

Figure 5a includes calculated cross sections in the cased part of the well and Figure 5b includes calculated values below the casing seat. The average cross-sectional area calculated for depths between 1507 and 2500 feet is equal to the known cross-sectional area of the 10 3/4-inch liner. This correct value of calculated area was forced by adjusting the scale factor for the nitrogen measuring system to 0.907. This same scale factor was used for calculation of cross-sectional areas below the casing seat. Below a depth of 2596.5 feet, the average cross-sectional area indicated by the lower graph of Figure 5 is 3239 square feet, with deviations of +45 and -42 percent. It is believed realistic to consider the cross-sectional area constant below a depth of 2596.5 feet, since the deviations can be attributed to interface errors of well under one inch. The average 3239 square foot cross section corresponds to a volume of 48.08 bbl/in. It is believed that errors in this value of volume do not exceed 50 percent.

<u>Nitrogen Leak Test</u>

Nitrogen injection into well 17 was completed on October 24 and interface depth measurements were begun on October 28. On October 29, the AGAR tool was removed from the well because of a concern that hurricane JUAN winds might cause wellhead damage with the long (about 20 feet) lubricator assembly attached to the wellhead. On November 1, the AGAR tool was put back in the well with an additional 5 feet of sinker bar and wellhead lubricator. Because of the different wellhead configuration, it was necessary to establish a new reference mark on the wire line and begin again with the interface measurements. Interface measurements were made on November 1, 8, 14, and 19 by lowering the AGAR tool into the brine, pulling the tool up slowly, stopping the tool when a light came on indicating the interface, and then measuring the distance between the reference points on the wellhead and wire line. Results obtained using this technique were not satisfactory.

On November 21, the technique for measuring interface depth was changed. With the AGAR tool slightly below the interface, the tool was raised in increments of less than 0.5 inch and stopped at each depth to see if the interface indicator light would come on. If it did, the reference distance would be measured. If it did not, within a few minutes, the sequence would be repeated until the interface was located, and the reference distance would then be measured. This process was repeated eight to ten times on nine separate days between November 21 and December 30. Results of these measurements are presented in Figure 6. A linear regression of the data of Figure 6 indicates the interface moving up at a rate of 0.00201 in/hr, with a standard error in rate of 12 percent. The calculated movement rate corresponds to a movement of 1.884 inches between the initial and final interface measurements spanning 937.3 hours. With the previously estimated borehole volume of 48.08 bbl/in, the interface movement rate corresponds to a volume change of 90.6 bbl between the initial and final interface measurements.

Nitrogen volume loss rate is calculated by use of the following equation (Eq. 4 of Ref. 1).

$$\Delta V_{id} \approx V_o \left[-\frac{\Delta P}{P_o} - \frac{\Delta V}{V_o} \right], \text{ where} \qquad (1)$$

ΔV_{id} = Volume lost measured at initial nitrogen density in well,

V_o = Initial total volume of nitrogen in the well,

P_o = Initial nitrogen pressure at the wellhead, absolute,

ΔP = Change in wellhead pressure during test period, and

ΔV = Change in nitrogen volume in well during test period.

Wellhead nitrogen pressure following completion of nitrogen injection into well 17 and cavern 15 pressures following completion of pressurization with oil are included in Figure 7. Nitrogen pressure readings have significant fluctuations due to the effects of daily temperature cycles on the pressure probe. These fluctuations make it difficult to determine the pressure change, ΔP, in the above equation during any time period of interest. In an attempt to more accurately define pressure values, temperature effects were analytically removed from the pressure data during the time that valid interface data were being obtained. This was accomplished by performing least square fits to the pressure results assuming a linear variation of pressure with both time and temperature:

$$P = a1 + a2 \times \text{hours} + a_3 \times {}^\circ F, \qquad (2)$$

where a_i are constants determined by the curve fit.

Measured pressure values are presented on expanded scale plots in Figures 8a (for times of 864 to 1344 hours) and 9a (for times of 1344 to 1824 hours). Corresponding measured probe temperatures are presented in Figures 8b and 9b. Least squares fits of the above equation to five-day segments of the data were made. The resulting equations are shown in Figures 8a and 9a, and the lines drawn in these graphs show the fit of the equations to the data.

The lower graphs, Figures 8c and 9c, include pressures corrected to the average temperature of the five-day segments of data and the fitted variations with time. The mismatches of the adjacent five-day segments of data are due to differences in average temperature.

The fitting equations at the top of the figures are used to determine pressures at the time of the first and last interface measurements of Figure 6. At a constant temperature of 72°F, the equations indicate a pressure of 1830.93 psig at 873 hours and 1832.51 psig at 1810.3 hours. It is believed that errors in pressure would correspond to a maximum error of 2 psi in pressure change during this time interval.

At completion of nitrogen injection at 203 hours, nitrogen volume in the well from the known volume of the casing plus the volume calculated from nitrogen weight measurements below the casing seat was 1002 bbl. Assuming the nitrogen volume change rate from 203 to 873 hours was the same as that measured between 873 and 1810.3 hours, the total volume at 873 hours, corrected to the lower pressure at that time, was 953 bbl. The above volume loss rate equation then yields:

$$\Delta V_{id} = 9.53 \left[- 1832.51 \quad 1830.93 \quad 1830.93 \quad - \quad -90.6 \quad 953 \right] = 89.77 \text{ bbl} \qquad (3)$$

With an elapsed time of 937.3 hours, this corresponds to a nitrogen volume loss rate of 840 bbl/yr. It has been proposed in Ref. 4 that it is reasonable to assume a value of 10 for the ratio of volumetric nitrogen-to-oil leak rates. With this assumption, the above nitrogen loss rate corresponds to 84 bbl/yr oil loss rate, compared to the DOE loss limit goal of 100 bbl/yr per cavern. Previously mentioned errors of SO-percent estimated maximum error in borehole cross-sectional area, 12-percent standard error in interface movement rate, and maximum estimated 2 psi error in pressure change, could correspond to an error in nitrogen loss rate as high as 70 percent.

Interaction Between Caverns 17 and 15

Because of the relatively thin web between caverns 17 and 15, any external communication of cavern 17 will probably be with cavern 15. It is thus important to look at pressures in the two caverns for any indication of such communication.

The pressure difference across the web between the two caverns at a time of 168 hours, shortly before beginning nitrogen injection into well 17, is shown in Figure 10. The pressure in cavern 17 was about 100 psi higher at the roof than that in cavern 15 at the same depth, and the difference increased with depth. At the end of the test, 1810.3 hours, the pressure in cavern 17 at the 2600-foot depth was 83 psi above that in cavern 15. Thus, any communication between these caverns during the test would be a fluid transfer from cavern 17 to 15.

There is nothing in the data of Figure 7 which indicate any communication between the two caverns. The pressure decrease in cavern 17 up to about 1100 hours is accompanied by increasing pressure in cavern 15. While this result is consistent with a transfer of liquid from cavern 17 to cavern 15, the pressures in both caverns vary in a manner normally expected for good caverns. That is, pressures decay after pressurization and shut-in, and the rate of decay decreases with time. After a few days for cavern 15 and a few weeks for cavern 17, the pressures begin to increase. By the end of the test, the pressures could be interpreted to indicate a near steady-state creep closure.

Figures 11 and 12 are expanded scale plots of oil pressure in cavern 15, oil pressure probe temperature, and five-day segments of pressure data corrected to average probe temperature. The format of the plots is the same as that for cavern 17 data in Figures 8 and 9. The effects of temperature on cavern 15 probe pressure reading are of lesser magnitude than those shown for cavern 17 results in Figures 8 and 9.

Pressure change rates from least squares fits of cavern 17 and 15 data from Figures 8, 9, 11, and 12 are summarized in Figure 13. These results indicate that for about the last 20 days (480 hours) pressure increase rates for the two caverns are roughly comparable.

While the pressures do not indicate any communication between the two caverns, it should be noted that sufficient evidence is not available to absolutely preclude such communication.

CONCLUSIONS

The test results indicate no reason to question the integrity of Bayou Choctaw cavern 17. Pressure variations with time are as would normally be expected for a good cavern.

A nitrogen leak test was made of well 17. The estimated well leak rate was 840 bbl/yr of nitrogen. This leak rate can reasonably be assumed to correspond to an oil loss rate of 84 bbl/yr, compared to the DOE loss limit goal of 100 bbl/yr per cavern.

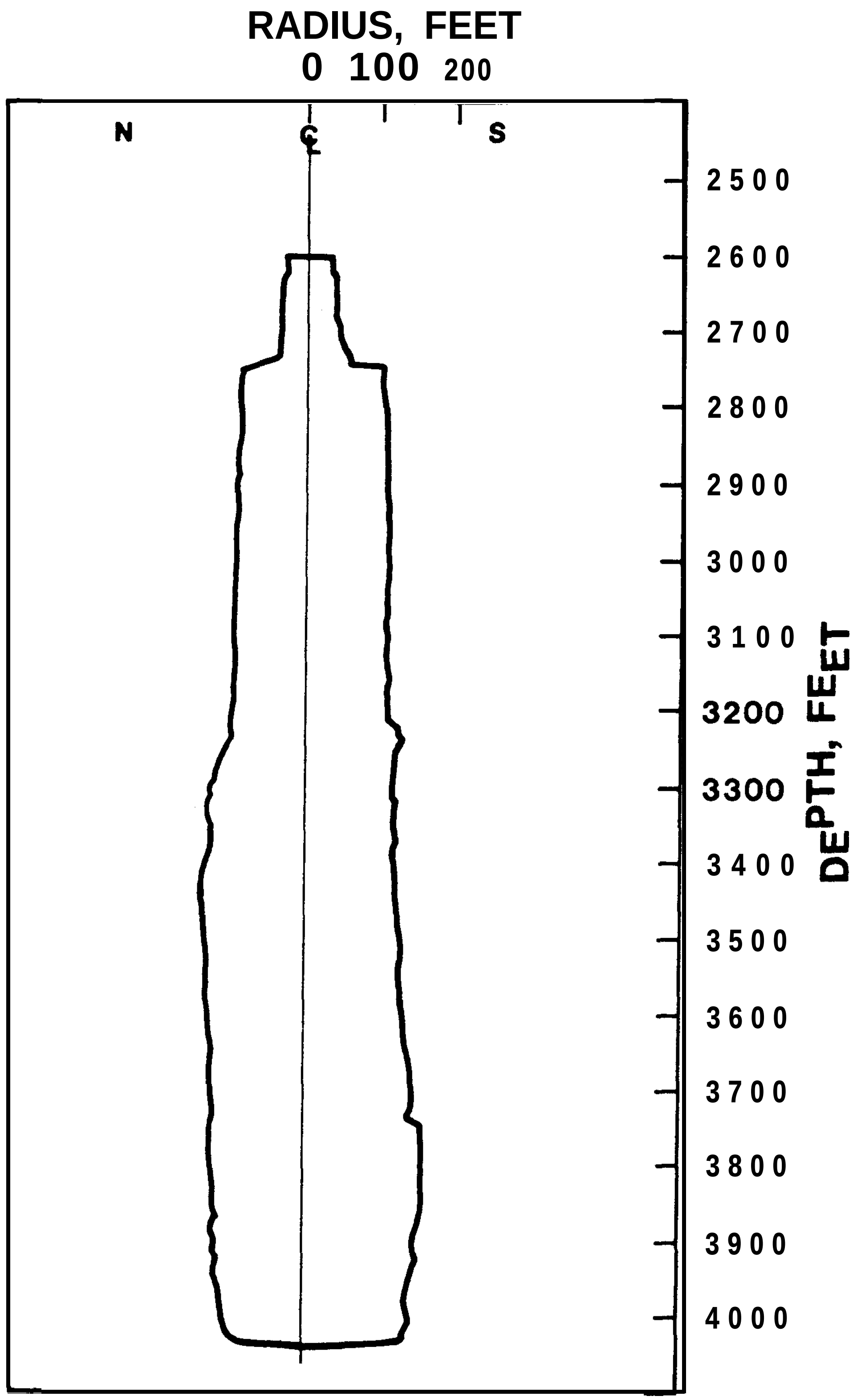


Figure 1. Sonar Caliper Survey of Bayou Choctaw Cavern 17 by "Sonar and Well Testing Services, Inc." on 9/30/85 (North-South Cross-Section).

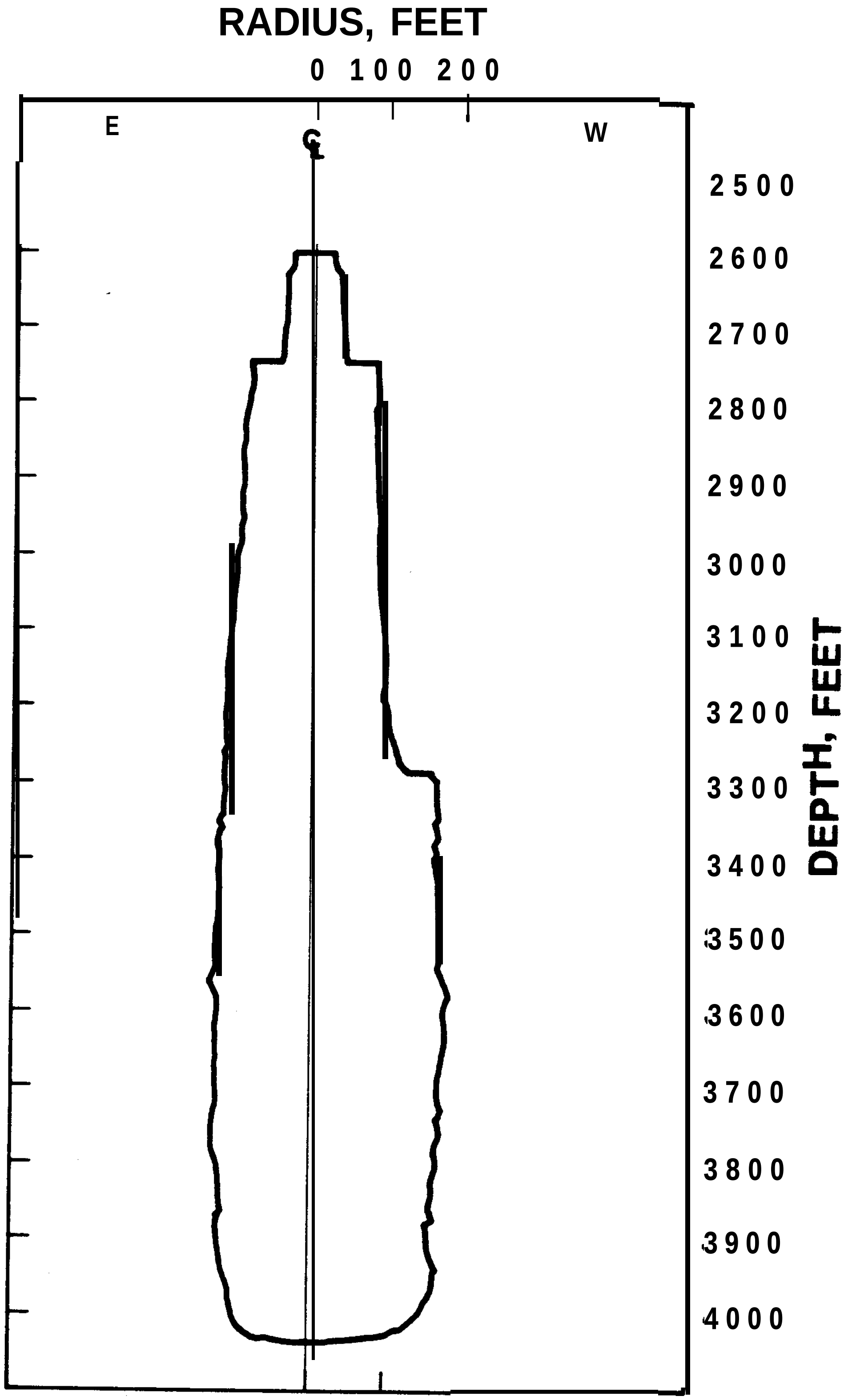


Figure 2. Sonar Caliper Survey of Bayou Choctaw Cavern 17 by "Sonar and Well Testing Services, Inc." on 9/30/85. (East-West Cross-Section).

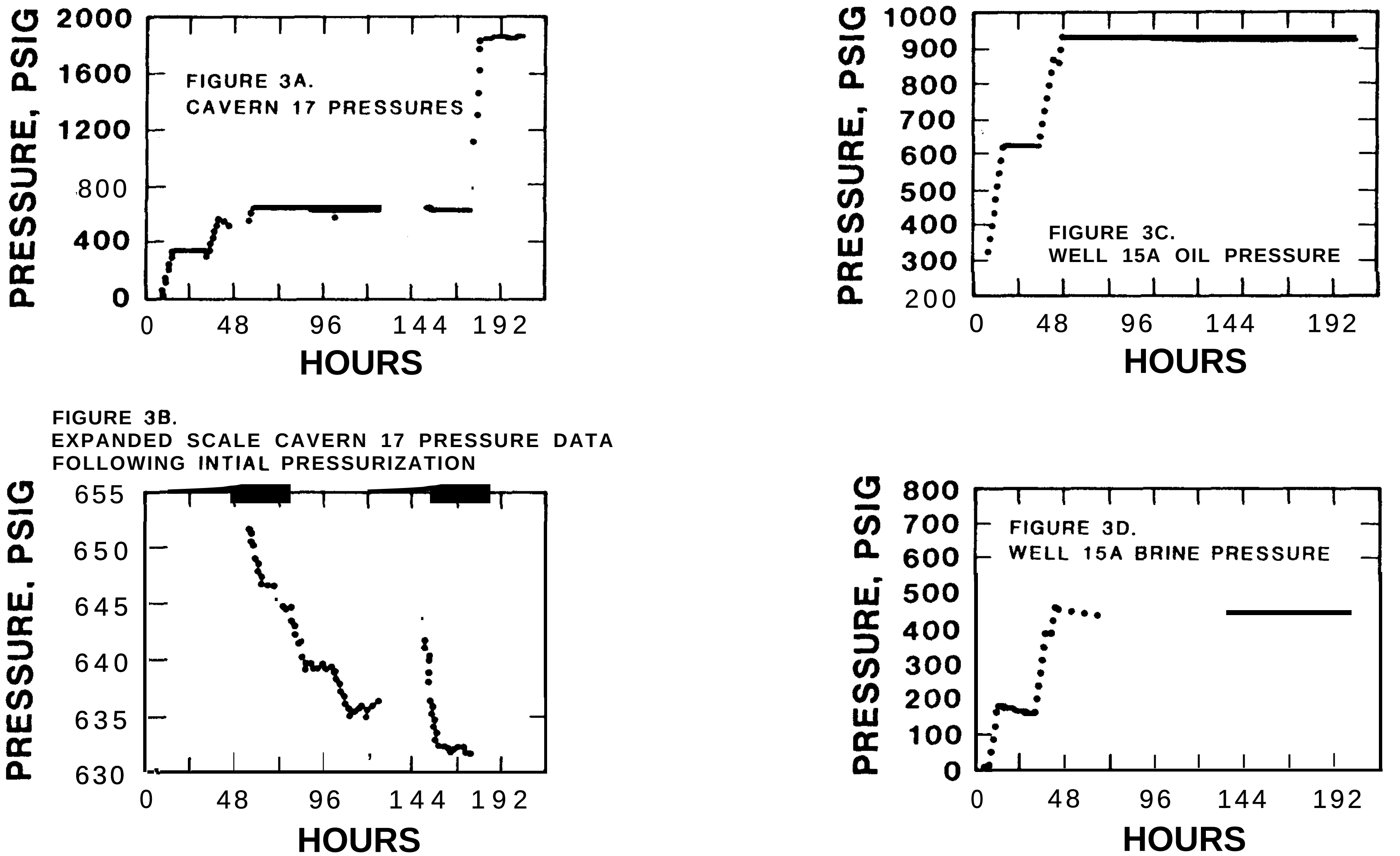


Figure 3. Cavern 1.5 and 17 Wellhead Pressures Up Through Time Nitrogen Injection into Well 17 Was Completed (Zero Hours at 00:00 on 10/16/85).

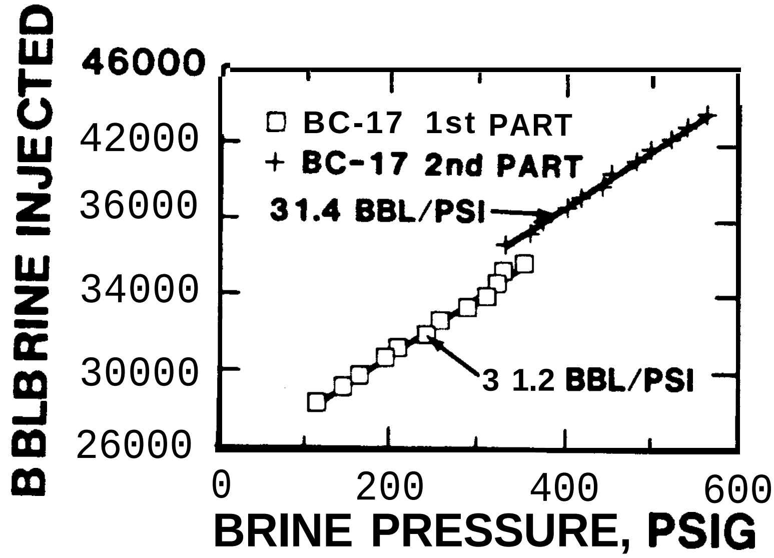


Figure 4a. Cavern 17 (some brine was unintentionally bled off between the first part data and the second part data).

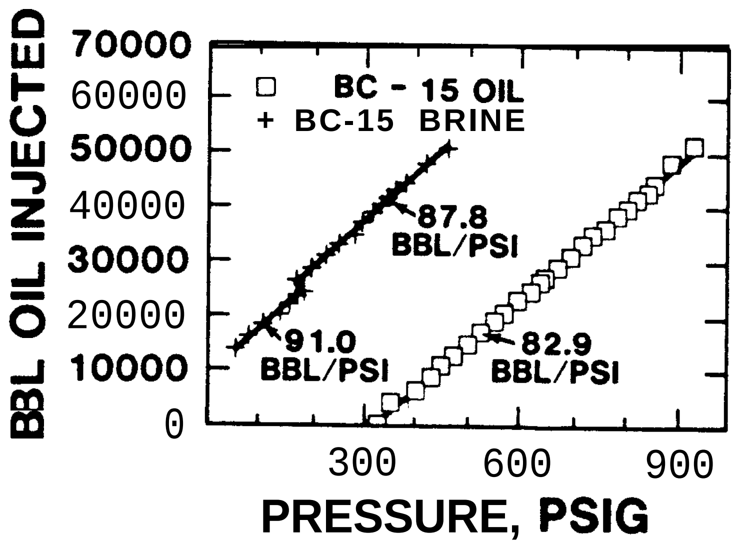


Figure 4b. Cavern 15.

Figure 4. Cavern Elasticity Results During Pressurization of Cavern 17 with Brine and Pressurization of Cavern 15 with Oil.

Interface Depth (ft)	Wellhead Pressure (psig)	Nitrogen Weight (lbs)
1507	1353.5	0
1600	1392.9	513.76
1700	1438.6	587.67
1800	14'3.6	615.94
1900	1531	612.31
2000	1573.8	690.21
2100	1616.2	632.24
2200	1661	774.63
2300	1704.7	731.86
2400	1748.1	841.29
2500	1792	701.45
254.0	1606.2	307.89
2545	1814	194.13
2560	1817.3	80.58
2570	1822.9	121.74
2580	1826.4	95.65
2590	1830.9	118.84
2596	1832.6	343.47
2596.5	1832.4	768.11
2596.682	1834.7	4782.56
2596.849	1838.4	5805.73
2597.042	1842	7310.07
2597.161	1847.1	5778.2
2597.266	1847.6	1998.53
2597.41:	1851	5701.39
2597.563	1652.6	4676.14
2597.667	1853.6	2043.45
2597.791	1855.7	4690.82

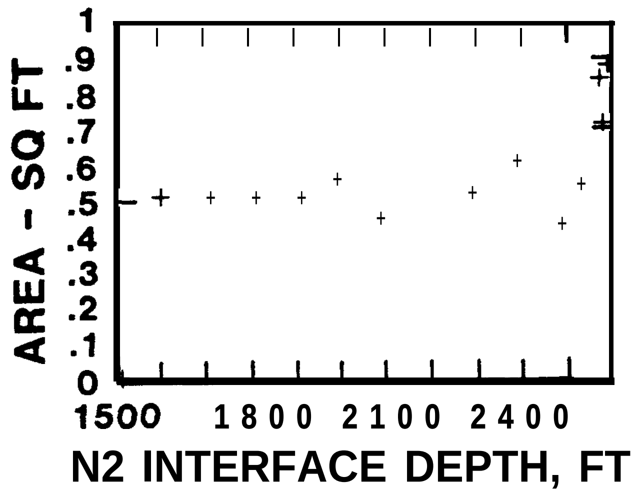


Figure 5a. Cased Part of Well.

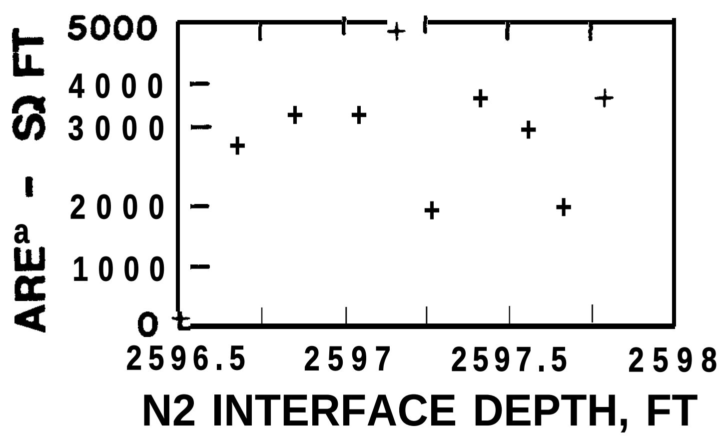


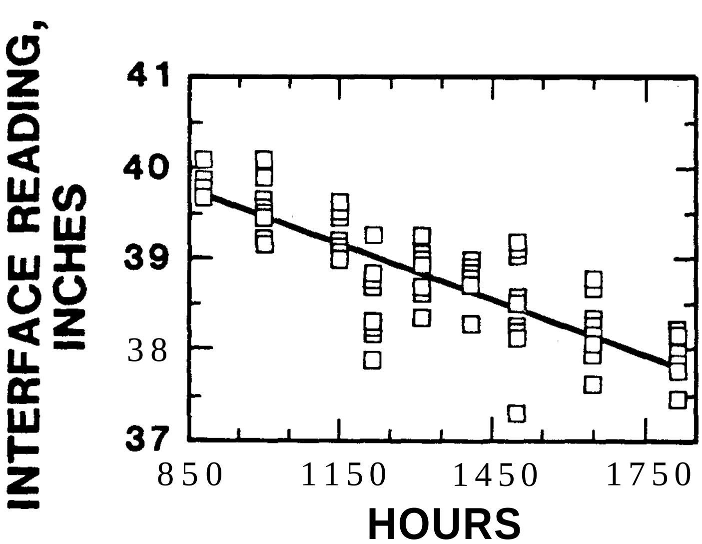
Figure 5b. Open Hole Below Casing Seat.

Figure 5. Calculated Cross-Sectional Area in Cased Part of Well and in Open Hole Below Casing Seat. (Assumed average nitrogen column temperature 100°F; weight measurement scale factor of 0.9071 required to calculate average cross sectional area of 0.5195 sq ft in part of well lined with 10-3/4-inch casing.)

Hours From Reference Times*	Inches From Ref Interface Depth†	Hours From Reference Times*	Inches From Ref Interface Depth†	Hours From Reference Times*	Inches Fmm Ref Interface Depth†
673	39.875	1210	36.75	1499	39.125
873	40	1210	36.1675	1499	39.0625
673	39.875	1210	37.9375	1499	38.5625
873	35 i5	1210	36.875	1409	37.3125
873	40	1210	38.75	1493	38.125
a73	40.125	1210	38.8125	1499	38.6
673	39.625	1210	39.25	1439	36.3125
673	39.75	1210	39.25	1499	38.5
		1210	38.125	1499	38.25
993.5	39.5625			1483	38.25
993.5	39.25	1311	38.625		
993.6	39.875	1311	39	1643.5	36.1675
933.6	40.0625	1311	38.375	1643.5	38.75
893.5	39.625	1311	39.1675	1643.5	36.3175
993.5	39.1875	1311	38.5625	1643.5	37.625
993.5	39.6875	1311	39.0625	1643.5	36.375
993.5	32.5625	1311	38.375	1643.5	38.625
		1311	39	1643.6	38
1143	39.4375			1643.5	36.1675
1143	39.9375	1407	38.625	1643.5	38.125
1143	39.25	1407	36.625		
1143	39.5	1407	38.75	1810.3	37.6125
1143	39.625	1407	36.6875	1610.3	38.1875
1143	39.0625	1407	38.8125	1610.3	38
1143	39.0625	1407	38.9375	1810.3	37.75
1143	39	1407	36.3125	1810.3	38.25
		1407	36.3125	1810.3	37.5
				1610.3	36
				1610.3	36.1675
				1610.3	37.675

*Reference time 00:00 hours on 10/16/85

†Reference interface depth is an arbitrary reference near the casing seat used for measurement of nitrogen-brine interface movement in the enlarged bore-hole below the casing seat.



FROM LINEAR REGRESSION

EQUATION FOR INTERFACE DEPTH MEASURED IN INCHES FROM AN ARBITRARY REFERENCE DEPTH IS : DEPTH = 4 1.464 - 0.0020 1 X HOURS

STANDARD ERROR IN MOVEMENT RATE IS 0.0002395 INCHES PER HOUR

Figure 6. Nitrogen-Brine Interface Depth Measurements.

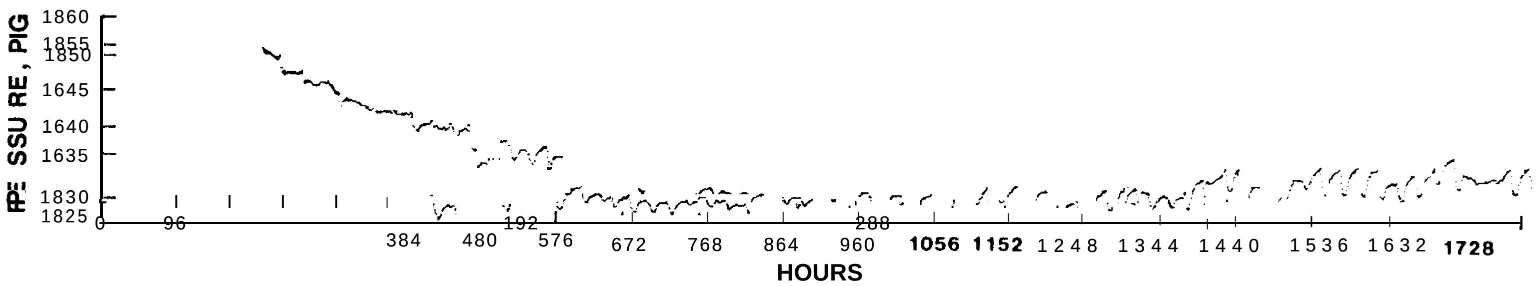


Figure 7a. Well 17 Nitrogen Pressure.

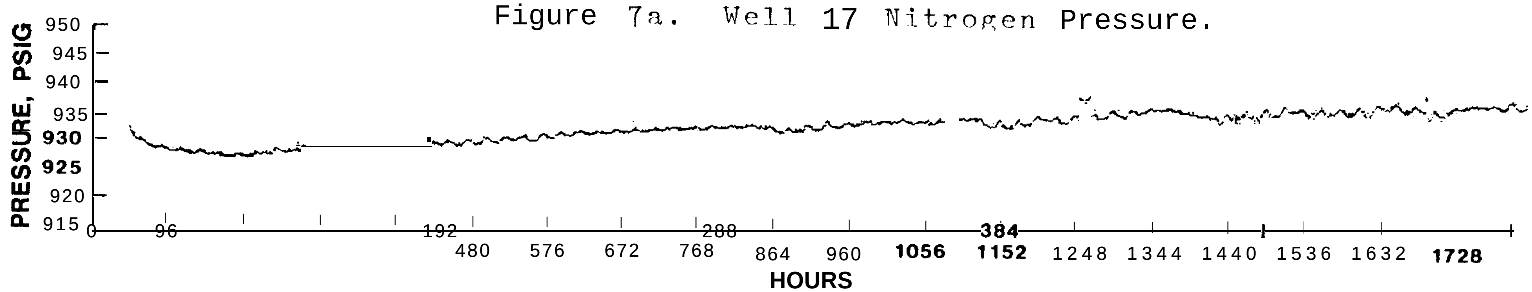


Figure 7b. Well 15A Oil Pressure.

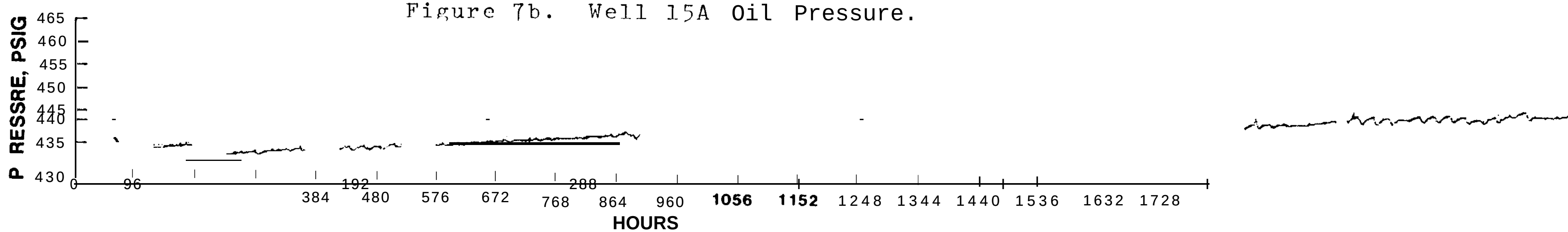


Figure 7c. Well 15A Brine Pressure.

Figure 7. Wellhead Pressures Following Cavern 17 Pressurization and Nitrogen Injection into Well 17 and Following Pressurization of Cavern 15 (zero hours at 00:00 on 10/16/85).

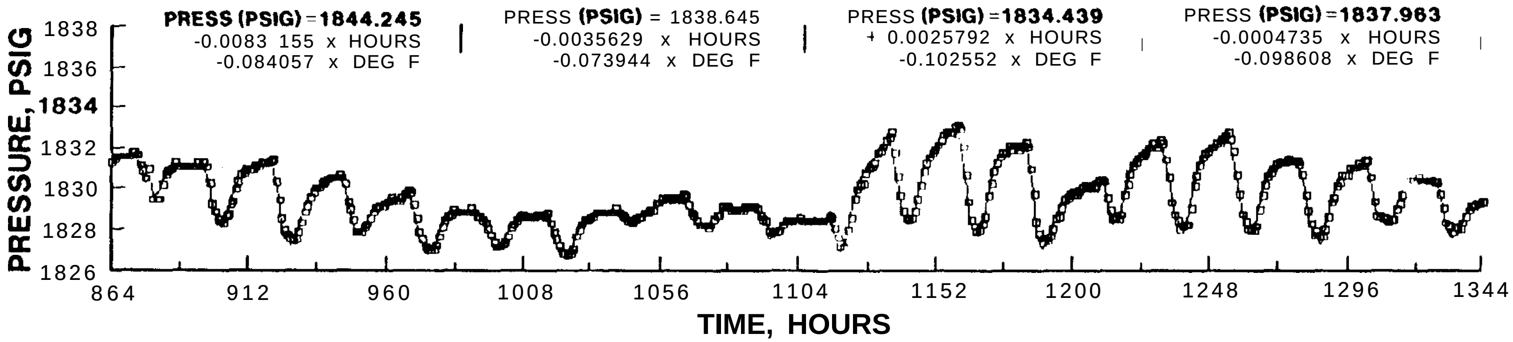


Figure 8a. Pressure Data Showing Mathematical Fit to Five Day Segments of Data.

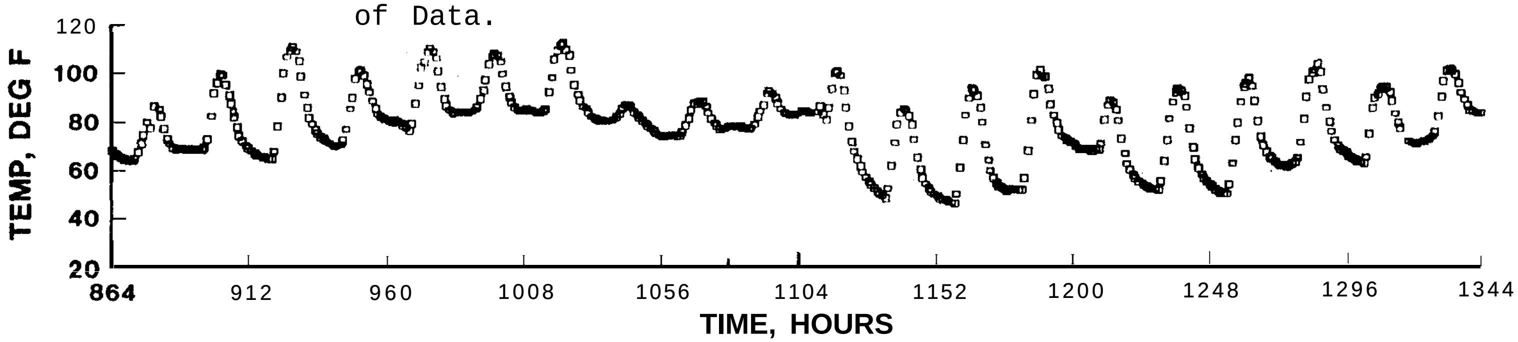


Figure 8b. Pressure Probe Temperature.

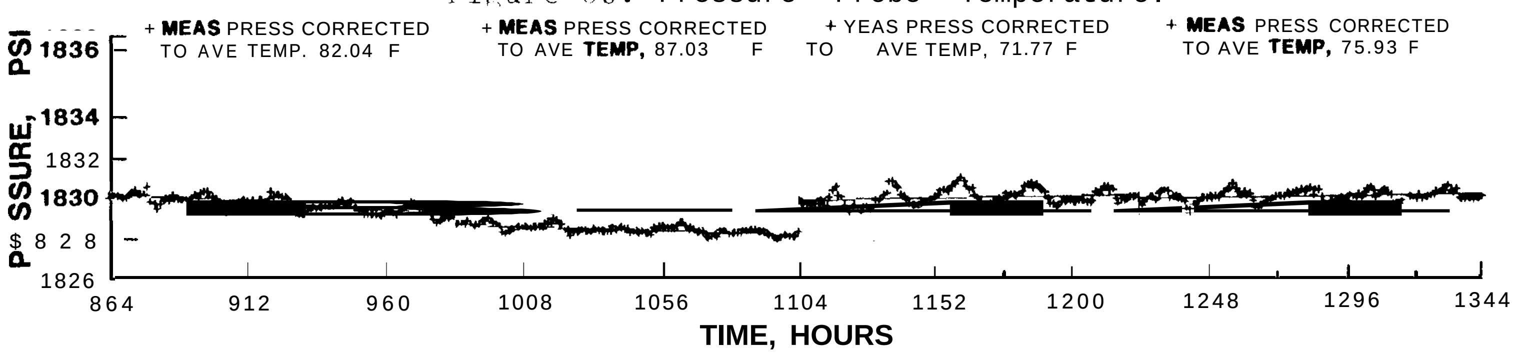


Figure 8c. Five Day Segments of Fressure Data Corrected to Average Temperature.

Figure 8. Bayou Choctaw Cavern 17 Wellhead Nitrogen Pressures an? Pressure Probe Temperatures During Early Interface Measurements. (Zero hours at 00:00 on 10/16/85.)

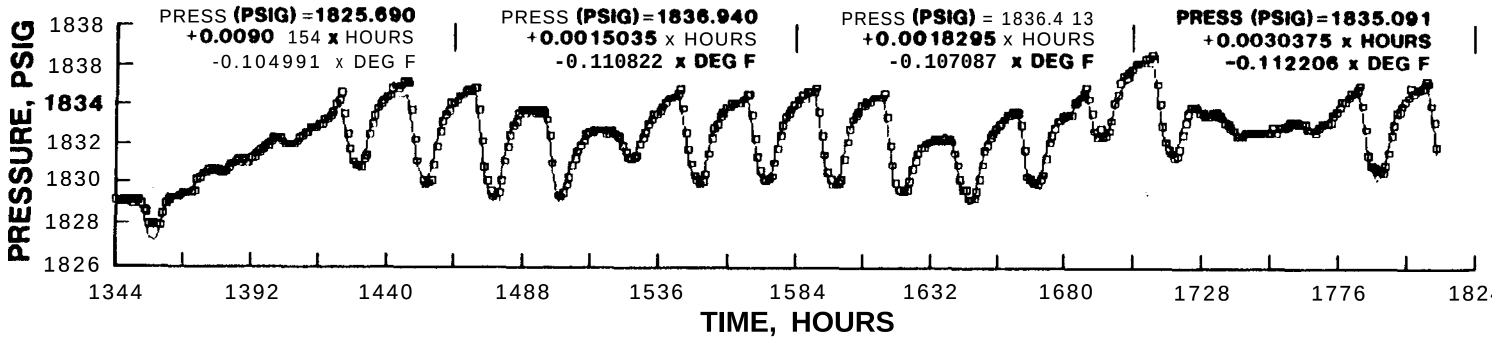


Figure 9a. Pressure Data Showing Mathematical Fit to Five Day Segments of Data.

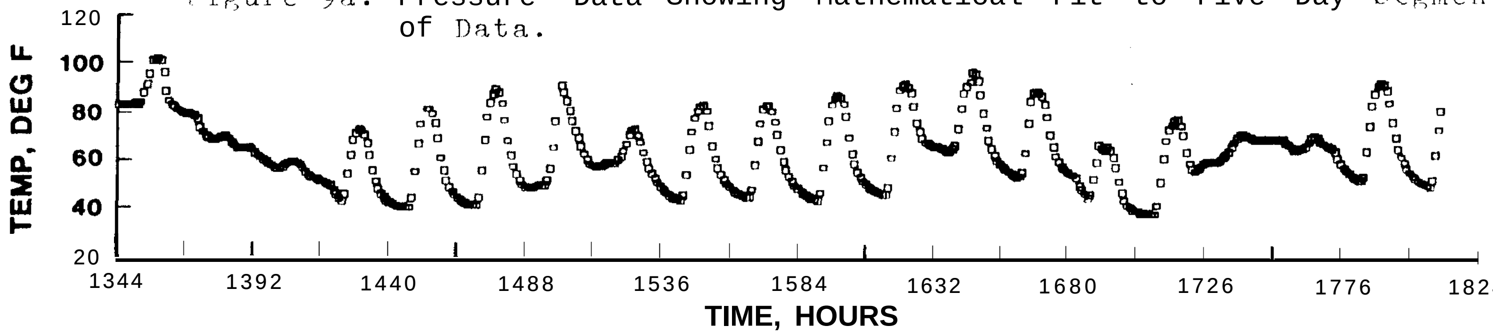


Figure 9b. Pressure Probe Temperature.

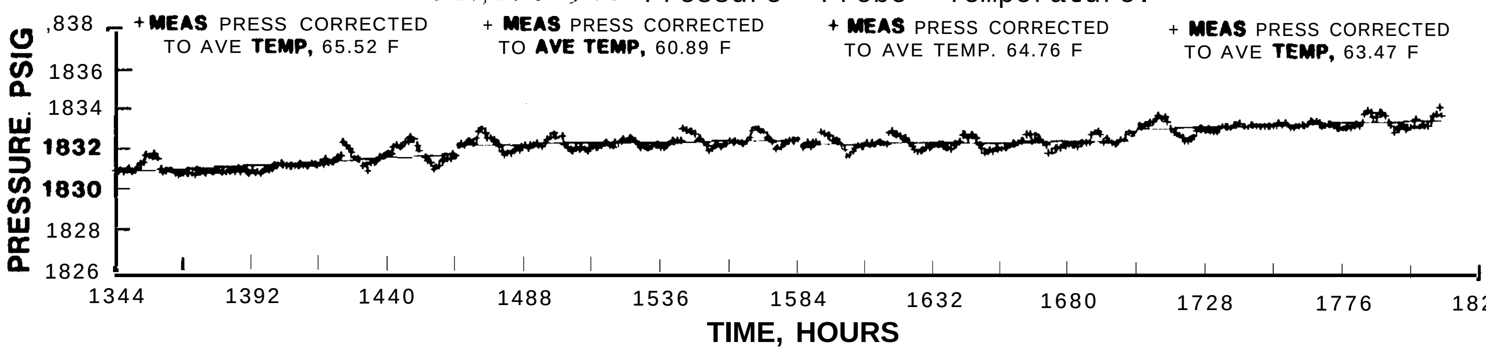


Figure 9c. Five Day Segments of Pressure Data Corrected to Average Temperature.

Figure 9. Bayou Choctaw Cavern 17 Wellhead Nitrogen Pressures and Pressure Probe Temperatures During Latter Interface Measurements. (Zero hours at 00:00 on 10/16/85.)

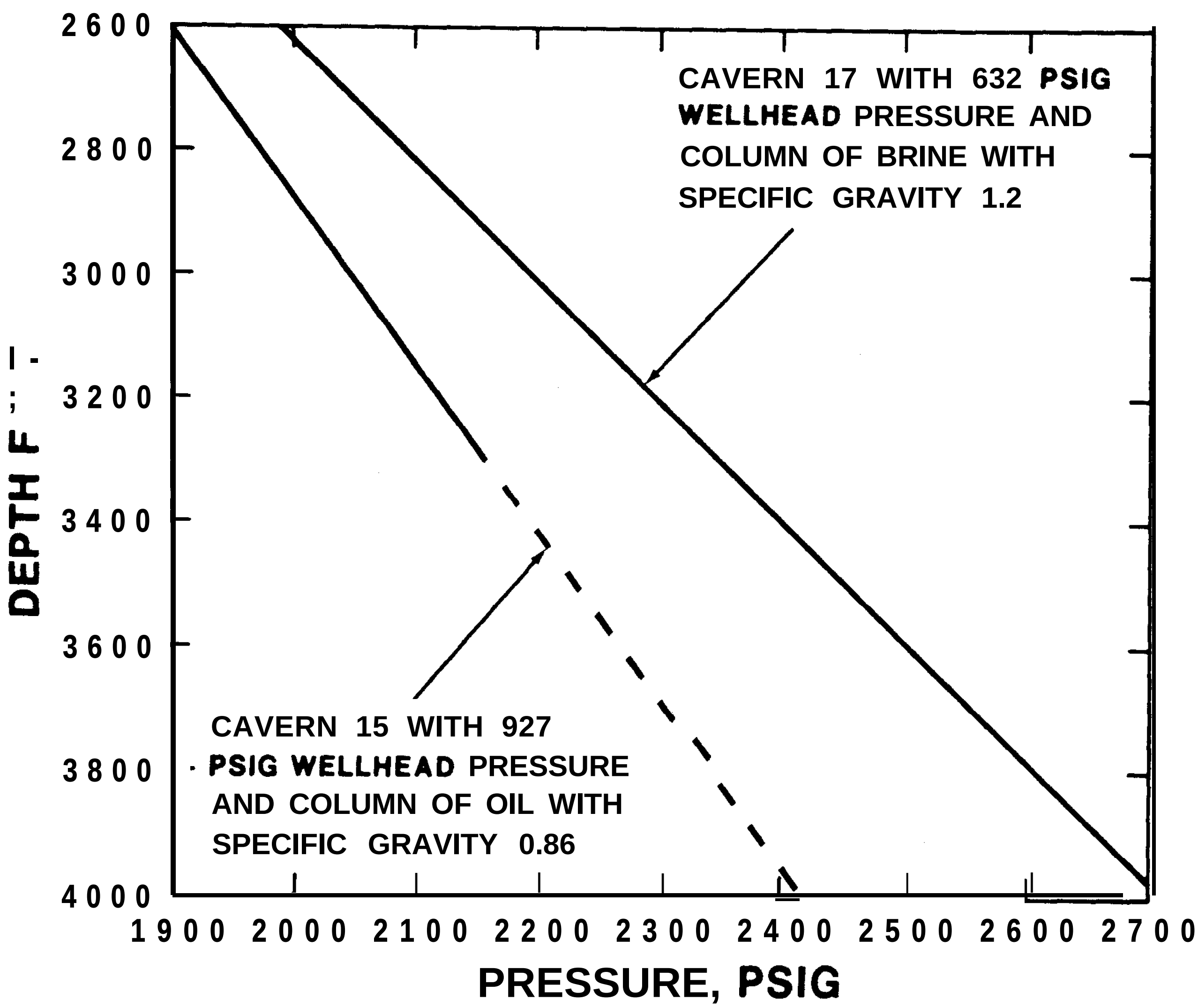


Figure 10. Down Hole Pressures in Caverns Bayou Choctaw 17 and 15 Indicating Pressure Difference Across Web Between the Two Caverns with Wellhead Pressures Measured at 168 Hours After Test Start (Cavern 17 Extends from Depths of 2630 to 4000 Feet and Cavern 15 Extends from Depths of 2600 to 3303 Feet).

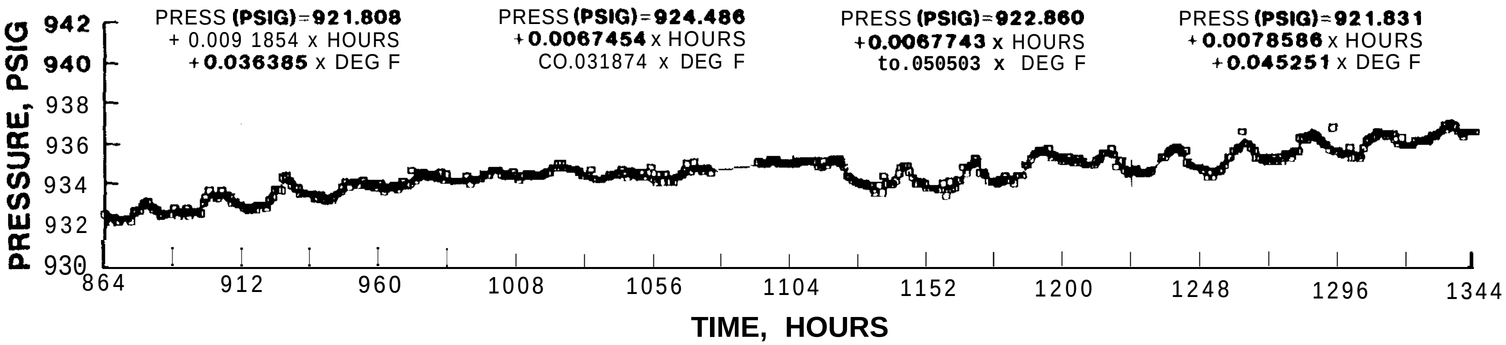


Figure 11a. pressure Data Showing Mathematical Fit to Five Day Segments of Data.

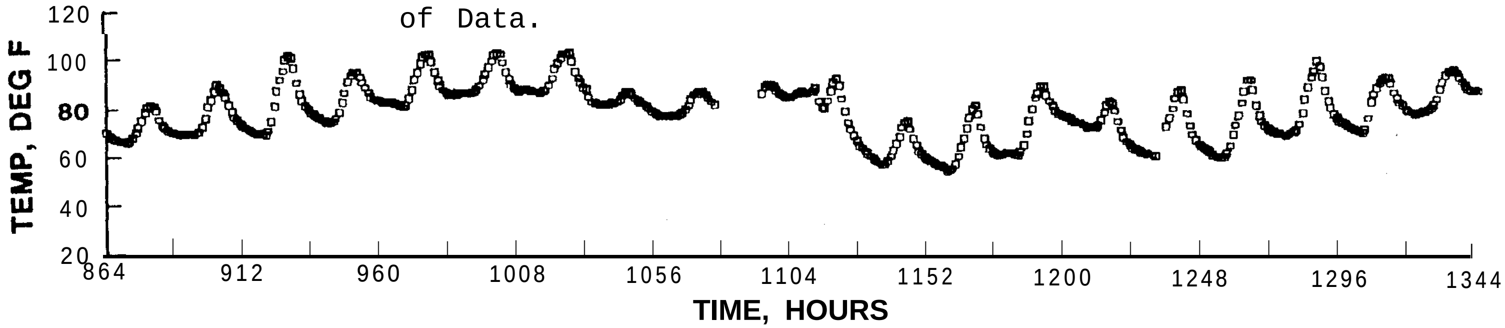


Figure 11b. Pressure Probe Temperature.

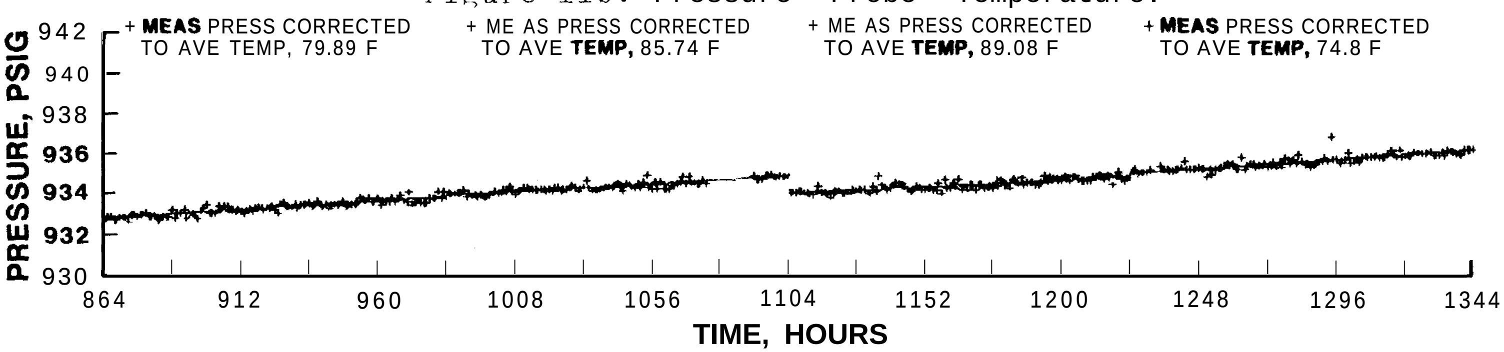


Figure 11c. Five Day Segments of Pressure Data Corrected to Average Temperature.

Figure 11. Bayou Choctaw Cavern 15 Wellhead Oil Pressures and Pressure Probe Temperatures During Early Interface Measurement in Cavern l?. (Zero hours at 00:00 on 10/16/85.)

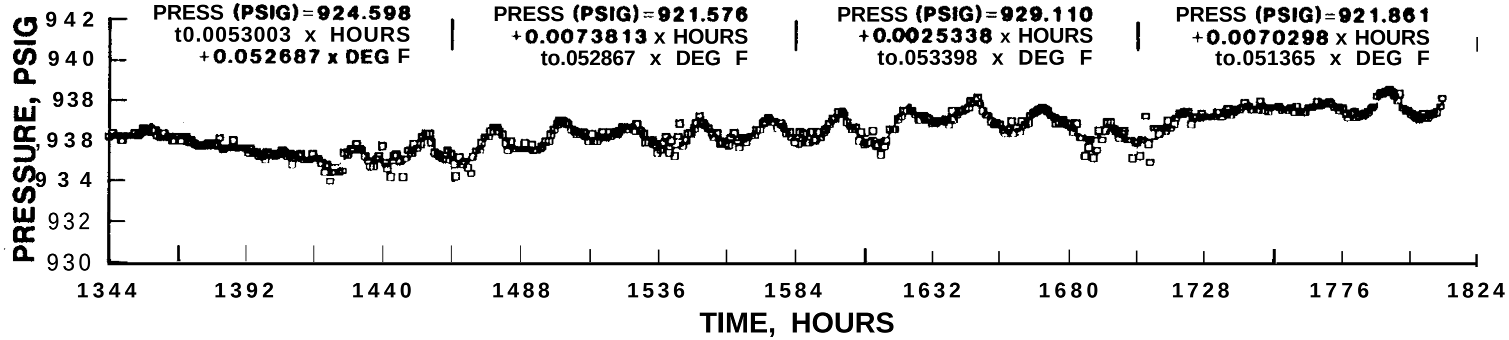


Figure 12a. Pressure Data Showing Mathematical Fit to Five Day Segments of Data.

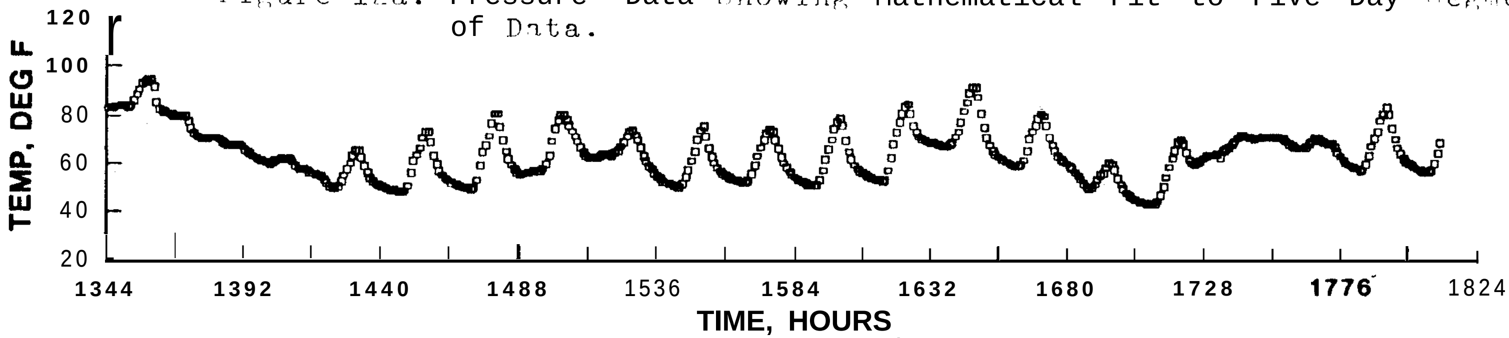


Figure 12b. Pressure Probe Temperature.

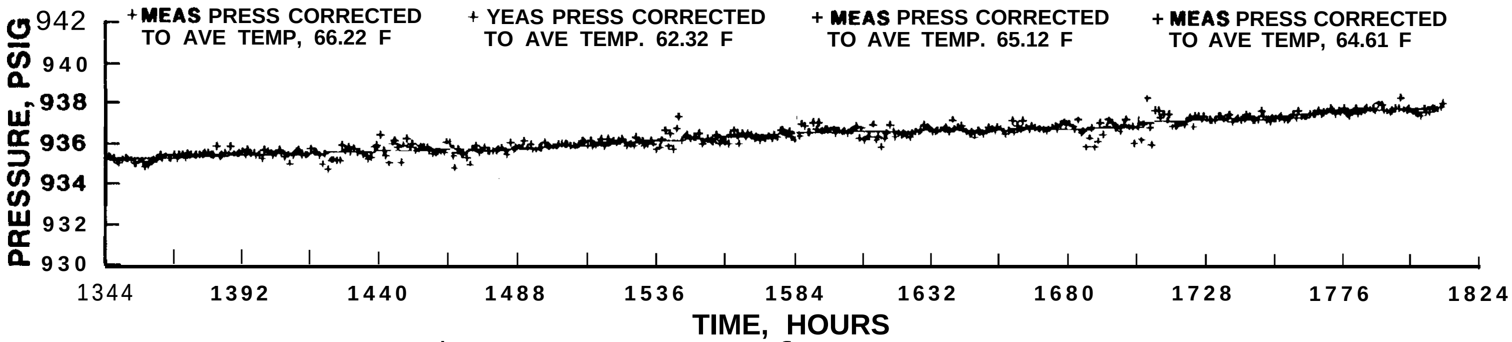


Figure 12c. Five Day Segments of Pressure Data Corrected to Average Temperature.

Figure 12. Bayou Choctaw Cavern **15** Wellhead Oil Pressures and Pressure Probe Temperatures During Latter Interface Measurements in Cavern 17. (Zero hours at 00:00 on 10/16/85.)

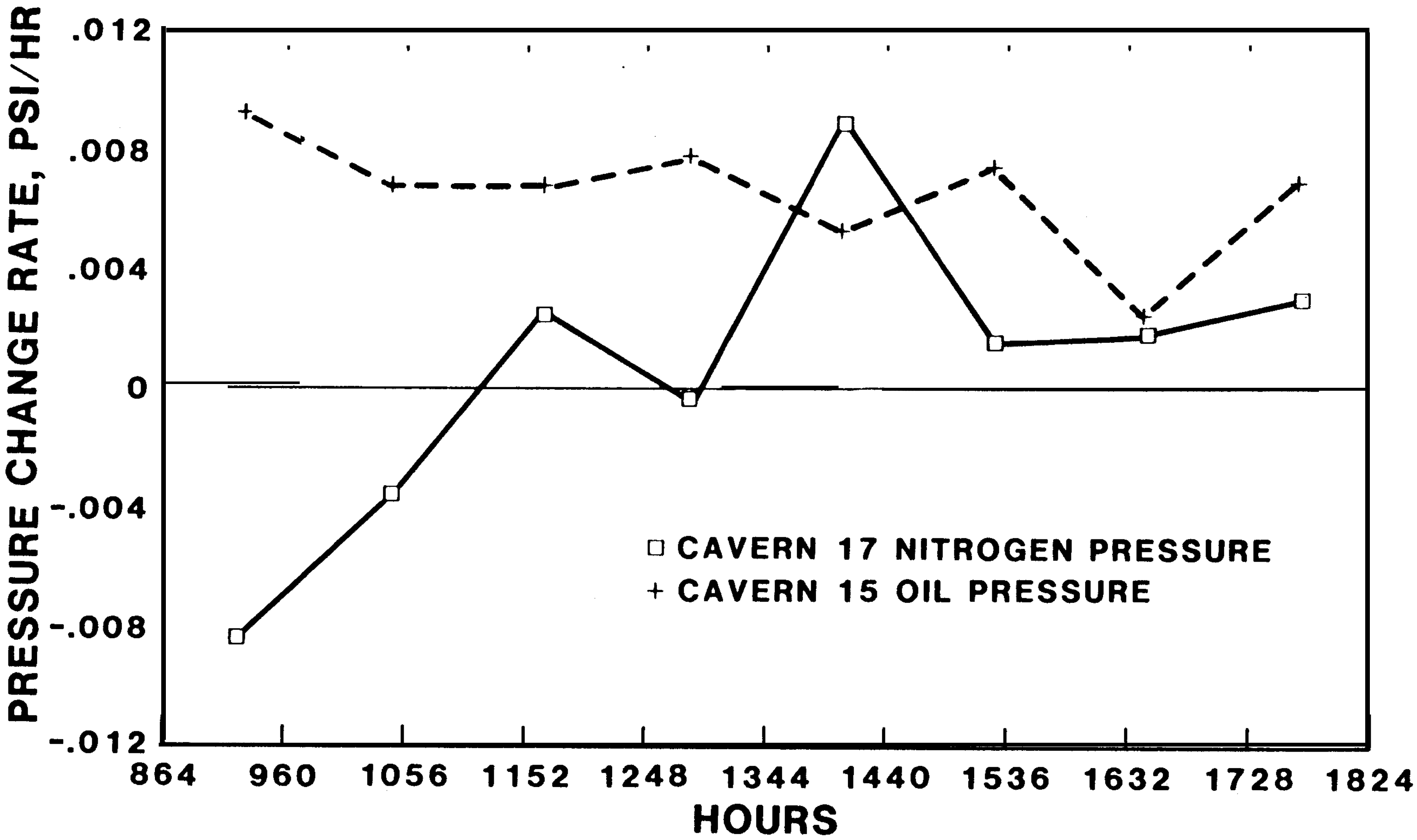


Figure 13. Pressure Change Rates from Sequential Five Day Segments of Data from Figures 8, 9, 11, and 12.

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